rf ion source development for neutron generation and for material modification

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rf driven multicusp ion sources have been successfully used in various different applications. Lately the Plasma and Ion Source Technology Group at Lawrence Berkeley National Laboratory has been developing a rf ion source for neutron production and a high current density cw-operated ion source for SIMOX (Separation by Implantation of Oxygen)-application. The group has developed a small ion source, which consists of a quartz plasma chamber, an external rf-antenna, an extraction electrode, and a target assembly, all in a tube that is approximately 25 cm in length and 5 cm in diameter. Another neutron generator currently under development is a multiaperture, high power generator. The neutron generator currently operates at 1% duty cycle, 80 kV, and 150 mA of deuterium beam. The neutron yield measured from the generator is 1.6×10^7 n/s. For oxygen implantation, the group has been developing a source which could provide a high percentage of O^+ at high current density using cw operation. A dual-antenna has been developed for the source to ensure reliable long life operation. The development of these sources will be discussed in this article. [DOI: 10.1063/1.1430519]

I. INTRODUCTION

The rf-driven multicusp ion source developed at Lawrence Berkeley National Laboratory has found numerous applications ranging from neutral beam injection systems for fusion reactors to particle accelerators, proton therapy machines, and ion implantation systems. Sources such as this are simple to operate, have a long lifetime, high gas efficiency also providing high-density plasmas with high yield of monatomic species. These characteristics make the rf multicusp source a viable candidate for compact, high-output, neutron generators and for ion sources for high current implanters.

II. EXPERIMENTAL SETUP

A. Large axial neutron generator

A large extraction area D^+-ion beam generator has been developed. The multicusp ion source in the experimental system is a stainless-steel, 30 cm diameter chamber surrounded with columns of samarium–cobalt magnets. The plasma is formed by rf induction discharge.

The ion beam extraction and acceleration system was simulated by using the IGUN[1] simulation code. The beam is being extracted through a multiaperture grounded plasma electrode with low extractor voltage. It is then accelerated with a third, single hole electrode. The third electrode is biased negatively to suppress the secondary electrons created by the beam from the target. The design allows the beam trajectories to crossover, which spreads the beam to a larger area. An example of the beam simulation in the extraction gap is shown in Fig. 1. For the experiments described in this article, a 61-aperture extractor was used with a combined beam extraction area of approximately 9 cm^2. The target was placed 50 mm from the third electrode downstream. In Fig. 2 the experimental setup is shown. The vacuum chamber is a standard 500 mm large-flange six-way cross.

B. Compact axial neutron generator

In addition to the large, axial neutron generator, a very compact neutron tube (2.5 cm in diameter) is being developed. This tube is designed to operate in a pulsed mode. In this generator, the plasma is also produced by rf induction, but the antenna is placed externally, outside a quartz plasma chamber. The accelerator in this tube is a single gap diode structure. The layout of the tube is shown in Fig. 3.

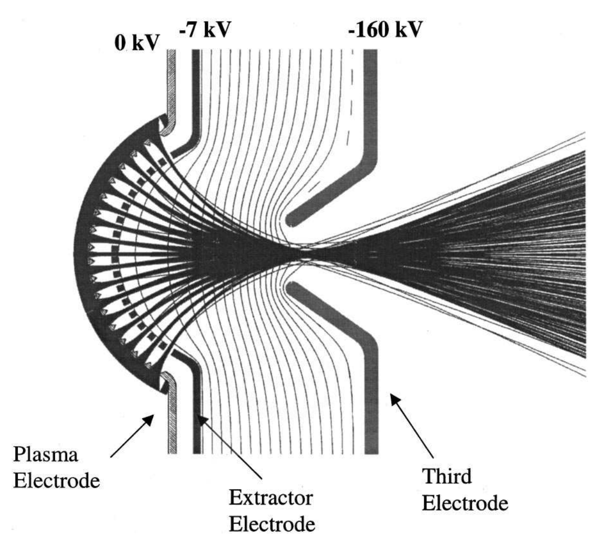

FIG. 1. The beam extraction geometry, simulated by IGUN beam extraction and transport code.

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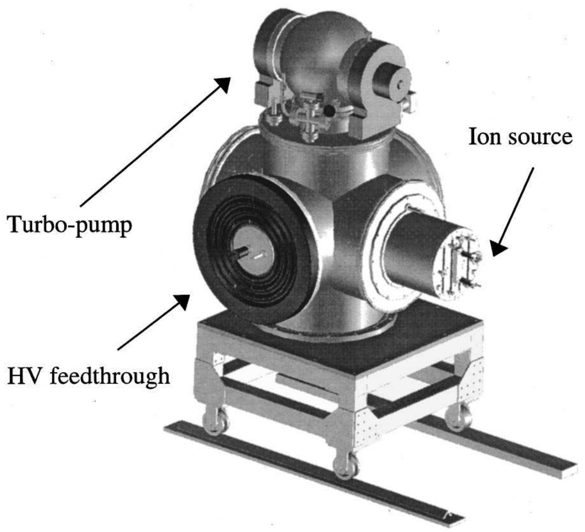

FIG. 2. The large axial neutron generator setup. The high voltage feedthrough is on the left, the turbovacuum pump unit is on top of the vacuum vessel, and on the right is the 30 cm in diameter, multicusp ion source.

C. rf ion source for O^+ implantation

An rf-driven ion source has been developed for high intensity oxygen beam production. The goal was to achieve at least 100 mA/cm^2 beam current density and more than 90% atomic species purity. The ion source has to be operated then at more than 4 kW of rf power. To achieve reliable cw operation at high rf-power levels, a new double antenna concept was developed. In this design, the rf power is divided into two parallel, quartz/titanium[2] antennas, see Fig. 4.

III. MEASUREMENTS

The neutron yield from the large axial tube was measured by ^{3}He detectors. In Fig. 5 the neutron yield is plotted as a function of time, when the generator is operated at 1% duty cycle. In this case the generator and the target was operated for the first time. The beam loading of the target is indicated by the rising neutron yield, eventually reaching a saturation.

The deuterium stays trapped in the titanium layer of the target for a fairly long period of time. This can be seen from Fig. 6, where the saturated yield is measured before and after a 20 h pause in operation.

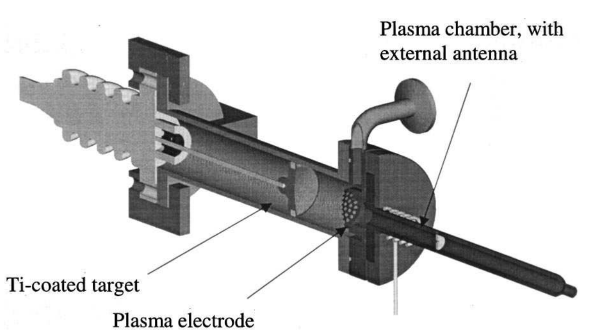

FIG. 3. The compact, 2.5 cm neutron generator layout. Plasma is formed in the quartz tube on the right, using an external rf induction antenna. The beam is then accelerated towards the titanium coated copper target.

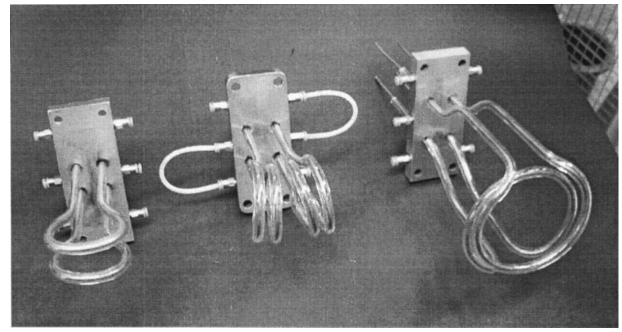

FIG. 4. Various different dual antenna concepts tested for reliable high power cw operation.

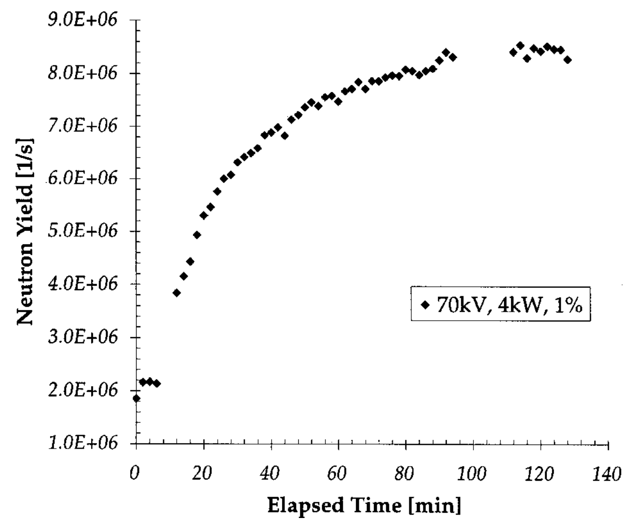

FIG. 5. Neutron yield as a function of time, after the generator is turned on for the first time.

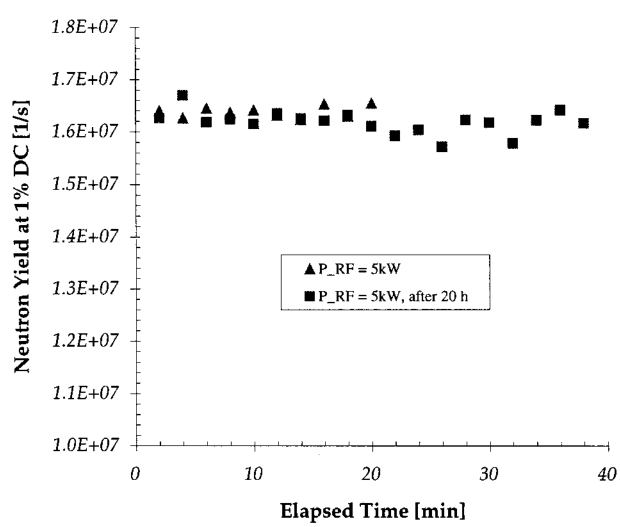

FIG. 6. Neutron yield as a function of time, before and after a 20 h pause in the operation.

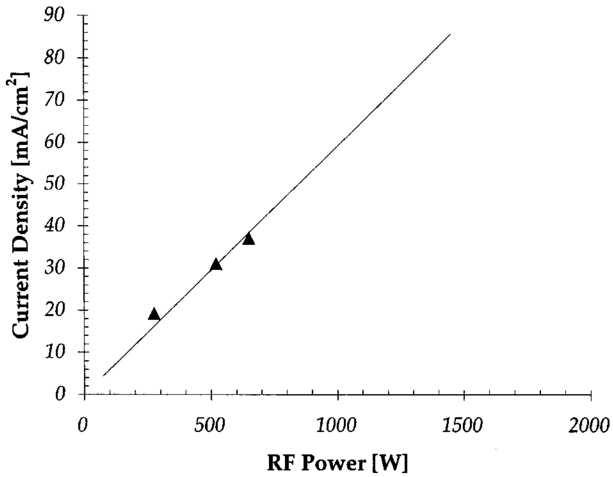

FIG. 7. The current density extracted from the compact axial neutron generator.

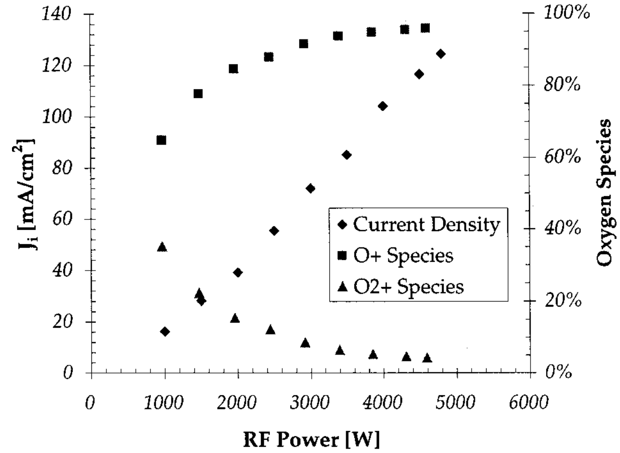

FIG. 8. The current density and the oxygen beam species extracted from the SIMOX implanter source.

For the compact neutron generator, the extracted current density is displayed in Fig. 7. In this measurement, hydrogen is used. If the generator is operated at 5 kW of rf power, the projected current density would be approximately 300 mA/cm^2.

The current density and the species measurements for the oxygen source are plotted in Fig. 8. The required beam properties can be achieved by using approximately 4.5 kW of rf discharge power.

IV. DISCUSSION

The large axial neutron generator will be operated in the near future with increased current and duty cycle. Projected neutron flux for the next phase is 10^{10} to 10^{11} n/s for D–D reaction. The compact tube will be operated with deuterium gas and the neutron yield will be measured.

ACKNOWLEDGMENTS

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